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Mexico: a bridge in Cuba–U.S. scientific collaboration

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Abstract
The collapse of socialist Eastern Europe in 1989 deprived Cuba's science system of its most important academic peers. To overcome this obstacle and increase its scientific productivity, Cuba drove scientific collaboration with countries in Europe and Latin America. This study explores the role of Cuban scientific collaboration with the U.S. in the absence of diplomatic relations between those countries. The results suggest that Mexico acts as a bridge for increasing scientific collaboration between Cuba and the U.S.—measured as the number of coauthored papers published in WoS and Scopus. When the number of papers co-authored by Cuban academics with their Mexican peers doubled, the number of articles coauthored by Cuban and U.S. scientists in Scopus grew 9.31 times $2^{3.22}$ and 8.11 times $2^{3.08}$. in WoS. The findings support the hypothesis that scientific collaboration favors an increase in the productivity and scientific visibility of countries. Furthermore, the results suggest that scientific collaboration helps to lay bridges between science systems in the absence of diplomatic relations and even in the presence of political and economic hostility between them. Strengthening international scientific collaboration makes it possible for the science systems of developing countries to overcome limitations on resources and carry out cutting-edge research, and also to incorporate their scientists in mainstream research in the areas that promote their technological-scientific development.

Keywords Co-authorship · Collaboration networks · Scientific collaboration · Scientific production · Power-law

Mathematics Subject Classification 00A99

JEL Classification Z210

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Introduction

In the first half of the twentieth century, the U.S. was the main academic partner of the Cuban science system (Ronda-Pupo, 2021). This collaboration disappeared in 1961 due to the embargo implemented by the U.S. that prohibits exchanges with Cuba (Fink et al., 2014; Pastrana & Clegg, 2008). Between 1962 and 1989, in the absence of diplomatic relations between Cuba and the U.S., the Soviet Union became the Cuban science system's most important scientific collaborator (Ronda-Pupo & Katz, 2016). This collaboration disappeared in 1989 after socialism collapsed in Eastern Europe, obligating Cuba to reformulate its international scientific collaboration strategy to overcome the lack of resources, develop cutting-edge research and increase the international visibility of its scientific results. So, international scientific collaboration contributed to the increase in Cuban scientific production and to the assimilation of emerging technologies in the areas of knowledge of interest for the country's scientific development (Palacios-Callender & Roberts, 2018; Palacios-Callender et al., 2016).

Prior publications confirm that international collaboration has a positive influence on the increase of scientific production of science systems (Bai et al., 2021; McManus et al., 2020; Shen et al., 2021). Beginning in 2000, Cuba implemented the geographical diversification strategy of its international scientific collaboration and prioritized encouraging scientific collaboration with countries from Asia, the European Union and Latin America (Ronda-Pupo & Katz, 2016). According to Cuban publications in WoS, Cuba went from collaborating with 91 countries in the decade of 1990–1999, to 196 in the decade of 2000–2010. During the decade of 2000–2009, Cuba significantly increased its scientific ties with China in Asia, with Spain in Europe and with Mexico and Brazil in Latin America. During this stage, Spain's science system participated in 17% of Cuban publications, while Mexico participated in 12%, Brazil 8%, and China 2%. In the following decade 2011–2020, Spain participated in 21% of Cuban papers, Brazil in 18%, Mexico in 19%, and China in 7%.

The diversification of international scientific collaboration allowed Cuba to increase its scientific productivity in the mainstream journals in the WoS and Scopus databases (Ronda-Pupo, 2021). The number of papers published by Cuba in the past 30 years in WoS increased fourfold, and sevenfold in Scopus, with an exponential curve.

Cuba and México have a long-standing cooperation relationship (Gilderhus, 2008). Although from 1950 to 1980, papers coauthored by scientists from both countries were limited, beginning in 1980, joint scientific productivity between both countries has increased sustainedly until the present-day, passing from one publication in 1982 to 264 joint publications in 2020.

On the other hand, it has been reported that Cuba's scientific collaboration with U.S. scientists and institutions shows a sustained increased over the past 40 years despite there being no diplomatic relations between these countries (Arencibia-Jorge et al., 2017). This behavior leads to the question: How has increased scientific collaboration between Cuba and the U.S. been possible since there are laws prohibiting exchanges between these countries? The trend seen in joint Cuba-U.S. scientific production in WoS and Scopus suggests extensive participation by Mexico's science system in these publications. For example, over the last decade, Mexican scientists co-appear in 48% of publications coauthored by Cuban and U.S. scientists. This trend suggests that Mexico is a bridge in the scientific collaboration of Cuban institutions and scientists with their peers in the U.S. in the absence of diplomatic relations between their countries.

Cuban scientific output at the macro level has not been frequently studied in the literature on Scientometrics (Arencibia-Jorge & de Moya-Anegon, 2010). International scientific collaboration between Cuba and Mexico and particularly its influence on bilateral Cuba-U.S. scientific collaboration has not been analyzed previously. The study sheds light on the effectiveness of the strategy of internationalizing Cuba's science system, specifically on the increase in scientific collaboration relations with the U.S. On the other hand, the study introduces the analysis of mediation of the scientific collaboration of a science system, in this case Mexico, in international scientific collaboration between two science systems, Cuba and the U.S., in the absence of diplomatic relations between them. This paper is intended to explore the mediator role of the Mexican science system in scientific collaboration between the Cuban and U.S. science systems. The objective of the research is specified through the research questions:

RQ1: Does Mexico's scientific collaboration with Cuba mediate the relationship between Cuba's international scientific collaboration, and Cuba–U.S. scientific collaboration?
RQ2: How much does Cuba–U.S. scientific collaboration–measured as the number of joint academic publications– increase with a growth –say double– in Cuba–Mexico scientific collaboration?

The results of the research are directed towards scientific policy planning and evaluation entities, academics who study international scientific collaboration and students and academics in the bibliometrics and scientometrics areas.

Materials and methods

Description of the models utilized in the research

In order to answer research question one, the *Mediation analysis* (Hayes, 2018) was used, and the *power law regression* (Reiss, 1989) was used to answer research question two. Table 1 summarizes the two research models used.

According to Hayes (2018), mediation analysis is a statistical method used to evaluate evidence from studies designed to test hypotheses about how a causal antecedent

Table 1 Summary of the research models

Variables	Model 1	Model 2
Dependent variable	Cuba–U.S. scientific collaboration	Cuba–U.S. scientific collaboration
Independent variable	Cuba international scientific collaboration	Cuba–Mexico scientific collaboration
Mediator	Cuba–Mexico scientific collaboration	No

variable X. transmits its effect on a consequent variable Y. Baron and Kenny (1986) state that a given variable functions as a mediator to the extent that it accounts for the relation between the predictor and the outcome. In the study, we examine the relationship between Cuban international collaboration, and Cuba–U.S. collaboration, with Cuba–Mexico scientific collaboration as the mediator. Figure 1 shows the conceptual mediation model 4 (Hayes, 2018). The model in Fig. 1 assumes a three-variable system such that there are two causal paths feeding into the outcome variable: the direct impact of the independent variable (path c) and the impact of the mediator (path b). There is also a path from the independent variable to the mediator (path a).

Baron and Kenny (1986) claim that a variable functions as a mediator when it meets the following conditions: 1) variations in levels of the independent variable significantly account for variations in the presumed mediator (i.e. path a.), 2) variations in the mediator significantly account f variations in the dependent variable (i.e. path b.), 3) when Paths a and b are controlled, a previously significant relation betwe the independent and dependent variables is no longer significant, with the strongest demonstration of mediation occurring when Path c is not zero. When Path c is reduced to zero, we have strong evidence for a single, dominant mediat. If the residual Path c is not zero, this indicates the operation of multiple mediating factors.

Equations 1.1 and 1.2 show the two required *linear models,* where i_M and i_Y are regression constants, e_M and e_Y are errors in the estimation of M and Y, respectively, and a, b and c' are the regression coefficients given to the antecedent variables in the model in the estimation of the consequents.

$$M = i_Y + aX + e_M \tag{1.1}$$

$$Y = iY + c'X + bM + e_Y \tag{1.2}$$

To estimate the indirect effect and its statistical significance we used the Sobel (1982) test Aroian version (Eq. 2) because the Aroian test corrects for standard error a and b, which is a drawback of the standard Sobel test. This test calculates the critical ratio as a test of whether the indirect effect of the independent variable on the dependent variable via the mediator is significantly different from zero. For practical interpretation of the results of this test, if the indirect effect is greater than the error, we would conclude that the addition of the Moderator variable changed the c path.

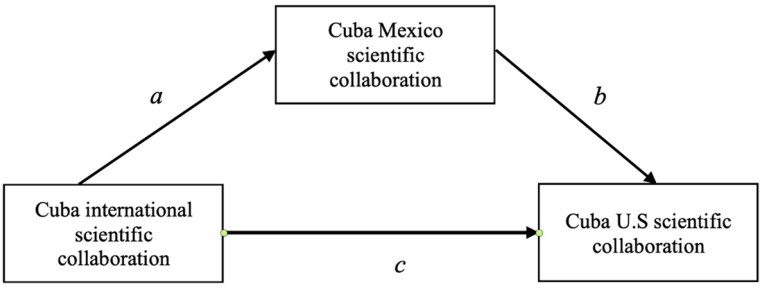

Fig. 1 Conceptual diagram of the mediation model. A simple mediation model is any causal system in which at least one causal antecedent X variable is proposed as influencing an outcome Y through a single intervening variable M (Hayes, 2018)

$$Z - value = \frac{a * b}{\sqrt{\left(b^2 * s_{a^2} + a^2 * s_{b^2} + s_{a^2} * s_{b^2}\right)}} \quad (2)$$

We also ran 5000 bootstraps to estimate the confidence interval of the indirect (mediation) effect. If the confidence interval does not cross zero, this implies a change in the *c* path.

The power-law regression was used to find the exponent that characterizes the rhythm of the increase in Cuban scientific production in collaboration with the U.S. through scientific collaboration with Mexico. For this, the allometric or power-law equation of Eq. 3 is used, in which y represents the dependent variable, Cuba-U.S. scientific collaboration, x is the scientific collaboration of Cuba with Mexico, and k, α are constants. In order to obtain the parameters k, α the logarithmic transformation of y and x is used, which results in a simple linear regression (Eq. 3.1).

$$y = kx^{\alpha} \quad (3)$$

$$\log(y) = \alpha \log(k) + \log(x) \quad (3.1)$$

Variables

Table 2 shows the variables used in the research models and their conceptualization.

The data

The study data consist of 810 papers published by the Cuban science system in Scopus and 769 in WoS between 1990 and 2020, inclusive. Cuban articles published with the participation of other countries were included in the study (international collaboration), as well as papers coauthored by Cuban researchers and their U.S. peers, and of these, the articles in which Mexican researchers and/or institutions participated. We used the query Advance search in WoS Core Collection CU = (Cuba) and PY = 1990–2020 and DT = (article or review or proceedings paper), citation indexes: Science Citation Index Expanded, Social Science Citation Index, and Arts & Humanities Citation Index. We analyzed the results and filtered the data using the label Country/region in WoS to select the Cuban papers that

Table 2 Variables and their conceptualization

Variable	Definition
Cuba international scientific collaboration	Cuban international scientific collaboration is measured as the number of papers published by the Cuban science system in the Scopus and WoS databases with the participation of academics from other countries
Cuba—U.S. scientific collaboration	Is the number of papers published by Cuba in Scopus and WoS with the participation of at least one academic from a U.S. institution
Cuba—Mexico scientific collaboration	Is the number of papers published by Cuba in Scopus and WoS with the participation of at least one academic from a Mexican institution

were published with the participation of at least one U.S. researcher, and with the participation of at least one author from Mexico. That way, co-authorship is used as an expression of scientific collaboration (Kahn, 2018).

To retrieve the productivity from the Scopus database we searched using Affiliation Country = Cuba, and filtered the results by Year: (1990–2020), Document Type (Article, Conference Paper, and Review), and Country/Territory (United States) to select Cuban scientific productivity in collaboration with the U.S. The results from the WoS and Scopus databases were combined using the R program bibliometrix (Aria & Cuccurullo, 2017), an open-source tool for quantitative research in Scientometrics. This program eliminates the duplicated articles that appear in WoS and Scopus.

Results

Descriptive analysis

Figure 2 shows an exponential increase in the participation of Mexico in papers coauthored by Cuban and U.S. researchers. This behavior suggests that the collaboration between Mexico and Cuba has contributed with the increased academic exchange between Cuba and the United States.

Figure 3 shows that the nucleus of the Cuban international scientific collaboration network is comprised of the U.S., Mexico and Spain. Mexico appears as a connector of the Cuban and U.S. science systems and also with science systems of Latin America and Caribbean countries. The network also indicates that the Spanish science system is a bridge between Cuba and Asian and European countries. This result will be confirmed in a later study.

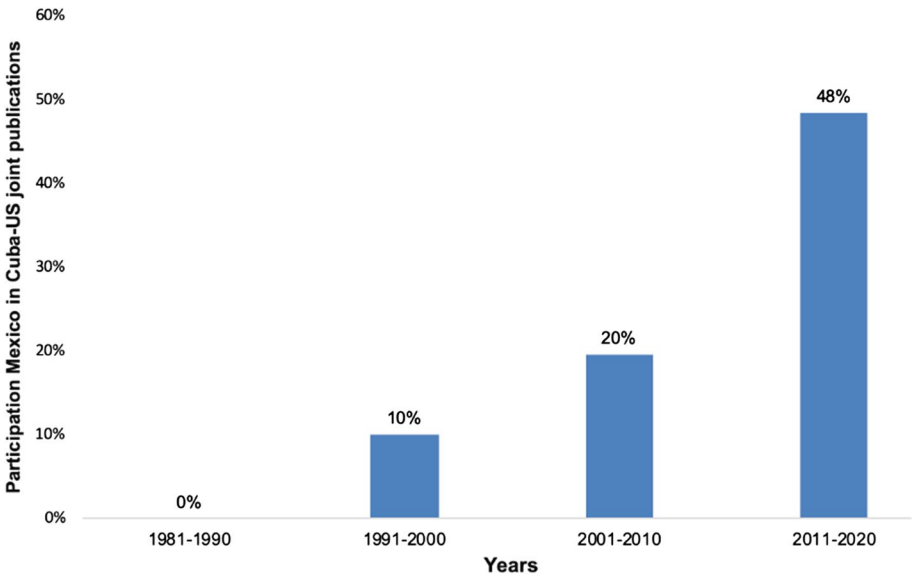

Fig. 2 Mexico's participation in joint scientific production between Cuba and the U.S

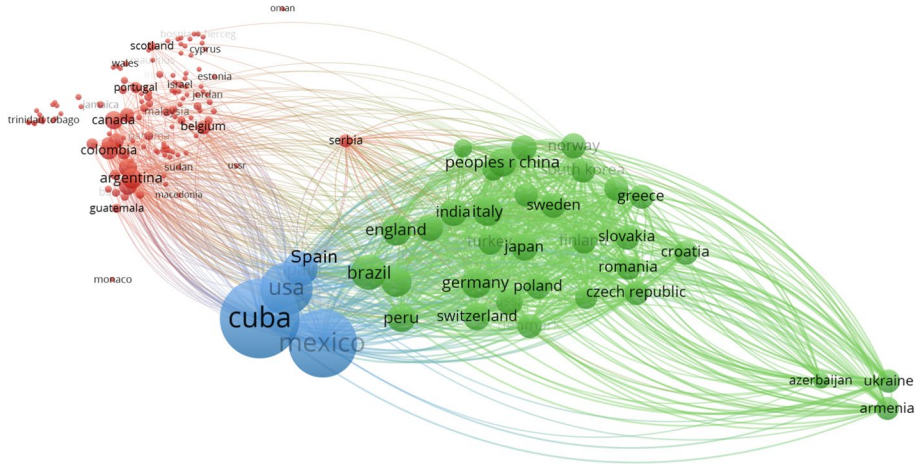

Fig. 3 International collaboration network in joint Cuba-Mexico publications. Note: Figure prepared using VosViewer. The size of the nodes is proportional to the degree of centrality of the country in the collaboration network

Figure 4 presents the scientific collaboration network at the university level. The collaboration network is comprised of 3446 scientific institutions from 156 countries. The figure shows an approach incorporating only universities from Cuba, Mexico and the U.S. The results show that Universidad Autónoma de México serves as a bridge between Cuban and U.S. universities. Also, Universidad de la Habana constitutes the central node of the Cuban universities (see Appendix 1). For the U.S., Yale University and Ohio State University are the most central of the network.

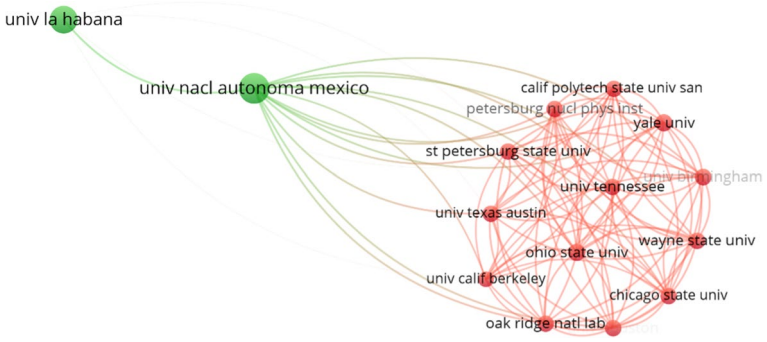

Fig. 4 Inter-institutional collaboration network in joint Cuba-Mexico publications. Note: Figure prepared using VosViewer. Institutions of countries that are not the subject of analysis in the study were left out of the network in order to better view the relationship between the institutions

Table 3 Overall model statistics for mediation analysis shown in Fig. 5

DV	IV	*b*	*SE*	*df*	*t*
Cuba-U.S. collaboration	Cuba Int scientific coll	0.24**	0.03	23	7.73
Cuba-U.S. collaboration	Cuba-Mx scientific coll	0.78**	0.12	23	6.74
Cuba-U.S. collaboration	Cuba-Mx scientific coll x Cuba Int Coll	0.33**	0.03	23	10.11

DV dependent variable, *IV* independent variable

**$p < 0.001$

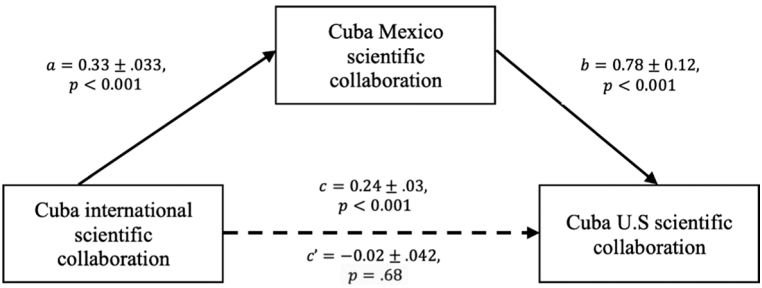

Fig. 5 Mediated relationship between Cuba international scientific collaboration and Cuba–U.S. scientific collaboration with Cuba–Mexico scientific collaboration as mediator

Answers to the research questions

RQ1: the mediation analysis

Cuba scientific international collaboration was used to predict Cuba–U.S. scientific collaboration, and the Cuba–Mexico scientific collaboration was expected to mediate this relationship. Data were screened for multivariate outliers, leverage, and influence. Other regression assumptions were assessed and indicated some skew and nonlinearity issues.

Table 3 presents the results of the mediation analysis. See Fig. 5 for a visual diagram of the mediated relationship. First, using steps described by Baron and Kenny (1986) along with updated mediation procedures (Hayes, 2018), Cuba international scientific collaboration predicts Cuba–U.S. scientific collaboration (the *c* pathway) $F(1, 23) = 59.70, p < 0.001, R^2 = 0.72$. $b = 0.33, t(23) = 10.11, p < 0.001$ a "much larger than typical" effect according to Cohen (1988) guidelines. Cuba international scientific collaboration increased the Cuba–U.S. scientific collaboration.

The Cuban international scientific collaboration predicting the Cuba–Mexico scientific collaboration (the *a* pathway) is significant $F(1, 23) = 102.30, p < 0.001, R^2 = 0.82$. $b = 0.24, t(23) = 7.73, p < 0.001$. a "much larger than typical" effect according to Cohen (1988) guidelines. The more Cuba's scientific system collaborates internationally, the greater its scientific collaboration with Mexico's science system.

The Cuba Mexico scientific collaboration predicting the Cuba–U.S. scientific collaboration (the *b* pathway) is significant $b = 0.78, t(23) = 6.74, p < 0.001$.. The greater Cuba's scientific collaboration with Mexico is, the greater its scientific collaboration with the U.S. science system will be. Additionally, the model shows that the Cuba scientific

collaboration together with Cuba-Mexico scientific collaboration predicting the Cuba-U.S. scientific collaboration is significant $F(2, 23) = 110.18, p < 0.001, R^2 = 0.91$.. The results show that when the Cuba-Mexico scientific collaboration enters the c' path, the Cuba scientific international collaboration no longer predicts the Cuba-U.S. scientific collaboration $b = -0.02, t(23) = -0.42, p = 0.68$.

The indirect effect was 0.26, 95% CI[0.13, 0.34]. Since the confidence interval does not include zero, we could conclude that the Cuba–Mexico scientific collaboration fully mediated the Cuba–U.S. scientific collaboration. The Sobel Aroian test $Z = 5.43 \pm 0,04, p < 0.001$, $Kappa = 0.26$ also coirms that there is a full mediation of Cuba-Mexico scientific collaboration in the relationship between Cuba scientific collaboration and Cuba-U.S. scientific collaboration. This result suggests that the increase of Cuba–U.S. scientific collaboration passes through collaboration with the Mexican science system. Mexico constitutes a bridge to Cuba–U.S. scientific collaboration in the absence of diplomatic relations between Cuba and the U.S.

The results confirm that the increase in Cuba's scientific collaboration with Mexico mediates the relationship between Cuba's international scientific collaboration and its scientific collaboration with the U.S., which is seen in the increase in number of papers coauthored by Cuban and U.S. scientists over the past 40 years. Although there are no prior studies on scientific collaboration between Cuba and Mexico to contrast the results of the study, the findings confirm the influence of international scientific collaboration in the increased international visibility of Cuban science system publications over the past 40 years (Palacios-Callender & Roberts, 2018; Palacios-Callender et al., 2016; Ronda-Pupo & Katz, 2016).

RQ2: the role of Mexico in increased Cuba–U.S. scientific collaboration

The results in Fig. 6 suggest that the scientific collaboration of Mexican academics with their Cuban peers contributed decisively to increasing Cuban scientific production in collaboration with academics from U.S. institutions. When the number of Cuban papers in collaboration with Mexico doubled, the number of Cuban papers published in collaboration

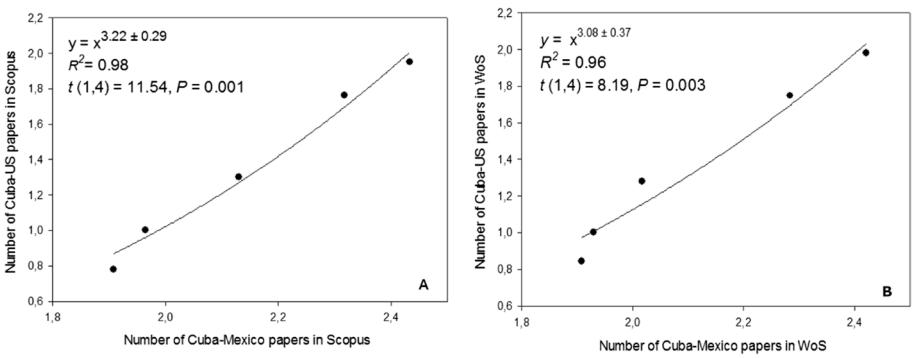

Fig. 6 Scaling relationship, at point in time. A Scopus: Durbin-Watson Statistic 1.81 Passed. Normality Test (Shapiro–Wilk) Passed $P = 0.32$. W Statistic = 0.88 Significance Level = 0.05. Constant Variance Test Passed $P = 0.06$. Power of performed test with alpha = 0.05: 0.96. B WoS: Durbin-Watson Statistic 1.66 Passed. Normality Test (Shapiro–Wilk) Passed $P = 0.99$. W Statistic = 0.99 Significance Level = 0.05. Constant Variance Test Passed $P = 0.06$. Power of performed test with alpha = 0.05: 0.90

with U.S. scientists increased 9.31 times $2^{3.22}$. in Scopus and 8.11 times $2^{3.08}$ in WoS. This result constitutes initial evidence on the mediation of scientific collaboration of a country in the bilateral scientific relationship between two economically and politically hostile countries. In this case, the U.S. and Cuba have not had diplomatic relations for over 60 years. Despite there being a legal prohibition through the embargo that impedes exchanges of all types between both countries, the results suggest that scientific collaboration is an effective diplomatic channel in the absence of other types of relations.

The results support findings in prior studs on the ascending relationship of international scientific collaboration with scientific productivity and its impact (Katz & Ronda-Pupo, 2019).

Effects of Cuba–Mexico collaboration on joint Cuba–U.S. scientific collaboration by domain and research field

Figure 7 shows that the domains of Natural Sciences, Applied Sciences and Health Sciences accumulate 97.3% of total Cuba–U.S. scientific production with the participation of academics from the Mexican science system. Collaboration is focused on the domains in which the Cuban science system has greater development and international visibility.

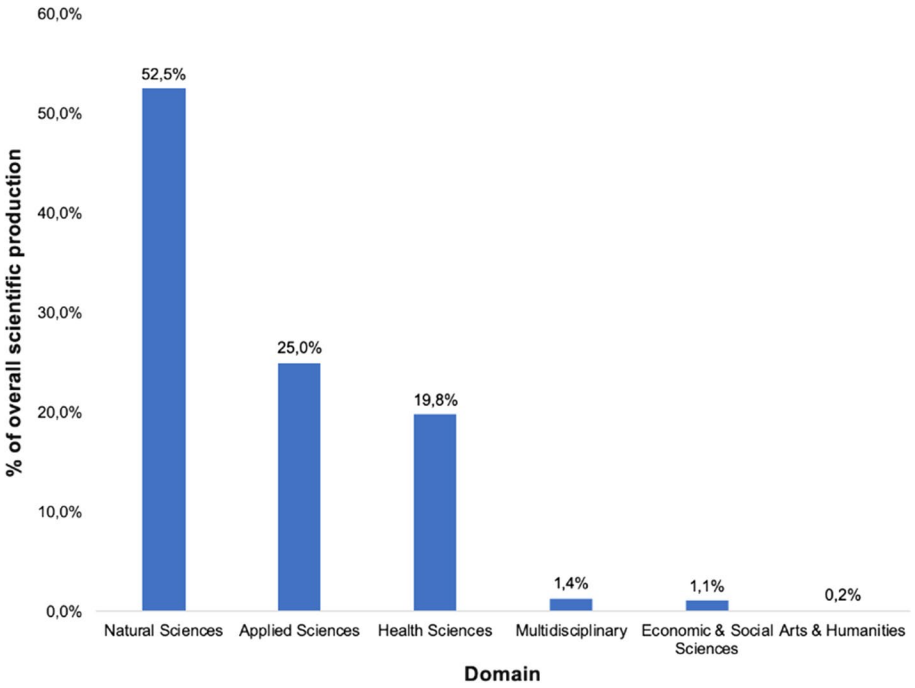

Fig. 7 Cuba-U.S. scientific production by scientific domain with the participation of Mexican academics. Papers are assigned to Fields according to Science Metrix journal classification, available from http://science-metrix.com/en/news/science-metrix-launches-the-second-public-release-of-its-multilingual-journal-classification. The information is based in the WoS, including the SCI-Expanded, SSCI, and A&HCI citation indexes. The Table includes only the number of documents published in Cuba-Mexico-U.S. cooperation. The query for the search is advance search *CU* Cuba and *PY* (year-year) and *DT* (article or review or proceedings paper). Analyze results = country/Regions

Table 4 shows the scientific production of Cuba in cooperation with the U.S. with the scientific participation of Mexico at the level of research fields. Four research fields, Physics & Astronomy, Clinical Medicine, Agriculture, Fisheries & Forestry and Enabling & Strategic Technologies, accumulate 61% of Cuban scientific production in collaboration with the U.S. It is significant that when only joint Cuba-U.S. productivity is analyzed (Ronda-Pupo, 2021), isolating the publications where Mexico participates, collaboration in Agriculture, Fisheries & Forestry and Enabling & Strategic Technologies is significant, which suggests that Mexico has contributed with scientific collaboration in areas that are relevant to driving the scientific and technological development of Cuba's science system.

Discussion and conclusions

The objective of the study is to explore the mediator role of Mexico's science system in the scientific collaboration between the Cuban and U.S. science systems in the absence of diplomatic relations between these two countries. The results of the study show that the scientific collaboration of Mexico and Cuba mediates the relationship between Cuban international collaboration and the scientific collaboration between Cuba and the U.S. With an increase by one unit (one paper with Cuban-Mexican collaboration), the scientific collaboration between Cuba and the U.S. increases by 0.25. This result suggests that

Table 4 Joint Cuba-U.S. scientific production by research field with the participation of Mexico

Fields	Number of papers	%
Physics & astronomy	1289	30.9%
Clinical medicine	475	11.4%
Agriculture, fisheries & forestry	393	9.4%
Enabling & strategic technologies	379	9.1%
Chemistry	359	8.6%
Biology	357	8.6%
Biomedical research	227	5.4%
Engineering	188	4.5%
Earth & environmental sciences	104	2.5%
Public health & health services	91	2.2%
Information & communication technologies	82	2.0%
Mathematics & statistics	82	2.0%
General science & technology	57	1.4%
Social sciences	44	1.1%
Psychology & cognitive sciences	33	0.8%
Historical studies	5	0.1%
Visual & performing arts	2	0.0%
Economics & business	2	0.0%
Built environment & design	1	0.0%
Communication & textual studies	1	0.0%
	4171	100.0%

The papers assigned to Fields and subfields according to Science Metrix journal classification schema

the Mexican science system has served as a bridge to establish and increase scientific collaboration bonds between Cuba's science system and its U.S. peer in the absence of diplomatic relations between both countries. Furthermore, Cuba-Mexico scientific collaboration contributed to the growth of Cuba's international scientific research network, by favoring an increase in the scientific collaboration of the Cuban science system with other Latin American and Caribbean countries, primarily with Brazil, Chile, Colombia and Argentina.

From the practical point of view, international scientific collaboration has favored the increase in the academic exchange of Cuba's science system with international researchers and institutions with a high performance in cutting-edge research. It has also favored the participation of Cuba's science system in subjects for its scientific, technological and economic development, through research in the fields of Agriculture, Fisheries & Forestry and Enabling & Strategic Technologies.

The results of the allometric regression suggest that when the number of Cuban articles coauthored with Mexican researchers doubles, the scientific collaboration between Cuba and the U.S. increases 9.31 times $2^{3.22}$ in Scopus articles and 8.11 times $2^{3.08}$ in WoS. This result confirms prior results on the hypothesis that international scientific collaboration is a favorable route for increasing scientific production in mainstream journals (Fu et al., 2022), and when there are limitations on material resources to develop cutting-edge research. In this particular case, it adds evidence of the benefits of scientific collaboration to overcoming political-legal barriers that hinder the direct relationship between two science systems.

The results suggest that scientific collaboration between academics of countries in conflict does not stop, even in times of war. Figure 8 shows the scientific collaboration, measured using the number of joint publications, of researchers before and during war between their countries of origin. The results suggest that there are no significant differences in scientific collaboration before and during the occurrence of war. Even when two countries declare war, their scientific communities maintain their scientific collaboration. Scientific communities put the scientific endeavor above any conflict between their nations. The

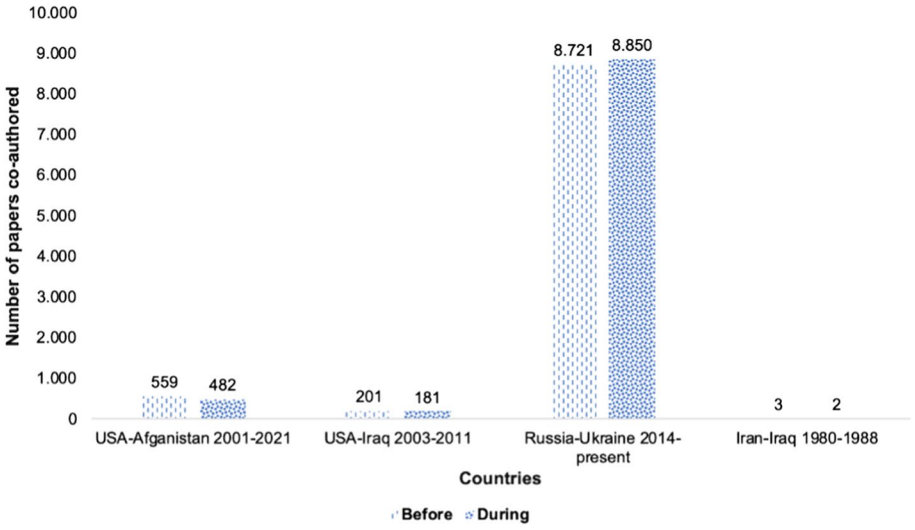

Fig. 8 Number of co-authored articles published by authors from countries at war. Note: source WoS, including Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index, and Emerging Sources Citation Index

results confirm that stated by Bruce Collette of the U.S. National Marine Fisheries Service Systematics Laboratory as cited by DeWeerdt (2001) "You can't embargo science."

Paired *t*-test: Normality Test (Shapiro–Wilk) passed ($P = 0.546$). $t = -0.178$ with 3 degrees of freedom. 95 percent two-tailed confidence interval for difference of means: − 146.258 to 130.758. Two-tailed *P*-value = 0.870. The change that occurred with the treatment is not large enough to exclude the possibility that the difference is due to chance ($P = 0.870$).

The results suggest that scientific collaboration is effective even when there is conflict between countries. In the particular case of the Cuba-U.S. dispute, scientific collaboration agreements between U.S. and Cuban institutions have contributed towards facilitating he exchange between Cuban and U.S. scientists. Examples of this are the agreement signed in the 1980s between the U.S. Smithsonian Institution and the Cuba's Academy of Sciences (CAS) and the agreement signed in the 1990's between New York Botanical Garden and the CAS (Pastrana, 2015).

The influence of scientific leaders has also helped to maintain scientific collaboration in the absence of Cuba-U.S. diplomatic relations, as in the case of the 2009 visit to the Cuban Academy of Science by the president of the AAAS, Peter Agre, accompanied by eight U.S. science leaders, aiming to foster cooperative projects to address a range of shared U.S.-Cuban scientific interests (Lempinen, 2009).

These last cases mentioned lead to other questions, such as: how do historical ties and collaboration agreements between countries have an influence on maintaining scientific collaboration when there are no diplomatic relations? Or: how do interpersonal relationships between researchers influence encouraging scientific collaboration in the absence of diplomatic relations between their countries of origin?

Appendix 1: The 25 Cuban and foreign institutions that appear most frequently in articles published by Cuba between 1990 and 2020 in WoS

Rank	Affiliations	Affiliation country	Record count	% of 20.361
1	UNIVERSIDAD DE LA HABANA	Cuba	4814	24%
2	UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO We thank reviewer 1 for his/her supporting words to our study	Mexico	1243	6%
3	UNIVERSIDAD CENTRAL MARTA ABREU DE LAS VILLAS	Cuba	1200	6%
4	CENTRO DE INGENIERIA GENETICA Y BIOTECNOLOGIA	Cuba	994	5%
5	UNIVERSIDADE DE SAO PAULO	Brazil	891	4%
6	INST CIENCIA ANIM	Cuba	851	4%
7	CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS CSIC	Spain	838	4%
8	UDICE FRENCH RESEARCH UNIVERSITIES	France	765	4%
9	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	France	723	4%
10	UNIVERSIDAD DE ORIENTE SANTIAGO DE CUBA	Cuba	720	4%

Rank	Affiliations	Affiliation country	Record count	% of 20.361
11	CINVESTAV CENTRO DE INVESTIGACION Y DE ESTUDIOS AVANZADOS DEL INSTITUTO POLITECNICO NACIONAL	Mexico	634	3%
12	INSTITUTO POLITECNICO NACIONAL MEXICO	Mexico	569	3%
13	UNIVERSIDADE ESTADUAL DE CAMPINAS	Brazil	513	3%
14	NATL CTR SCI RES	France	487	2%
15	UNIVERSITE PARIS SACLAY	France	477	2%
16	UNIVERSITY OF CALIFORNIA SYSTEM	USA	445	2%
17	HELMHOLTZ ASSOCIATION	Germany	438	2%
18	RUSSIAN ACADEMY OF SCIENCES	Russia	410	2%
19	ISTITUTO NAZIONALE DI FISICA NUCLEARE INFN	Italy	405	2%
20	SAPIENZA UNIVERSITY ROME	Italy	403	2%
21	BENEMERITA UNIVERSIDAD AUTONOMA DE PUEBLA	Mexico	401	2%
22	UNIVERSITY OF TEXAS SYSTEM	USA	401	2%
23	GOETHE UNIVERSITY FRANKFURT	Germany	398	2%
24	UNIVERSITY OF OSLO	Norway	396	2%
25	RUPRECHT KARLS UNIVERSITY HEIDELBERG	Germany	389	2%
	TOTAL (WoS 1990–2020)		20361	100%

The data consider total Cuban scientific productivity in WoS from 1990 to 2020.

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